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Sleep intensity and sensory processing during sleep: an auditory event related potential study.

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Introduction

Stimulus processing is evidently present during sleep. To which extent information processing still functions during sleep is unclear and undefined. Auditory stimuli have been used as an indication of sensory processing. Auditory event related potentials (AEPs) can be measured during waking, but also during various stages of sleep (Campbell et al., 1992). These authors noted that the wake-up threshold for auditory stimuli is higher during the first several hours of NREM sleep as compared to later NREM sleep episodes. This may be related to the initial high sleep intensity during the first several hours of NREM sleep, as can be measured by the EEG power in the slow wave (0.5 - 4.0 Hz) range.

We explored the possibility that EEG phenomena may indicate the relation between auditory processing during sleep and sleep intensity. We measured AEPs during NREM sleep and associated the AEP amplitude with slow wave activity during subsequent NREM sleep episodes.

Methods

One healthy 21 year old female subject participated in this experiment. Prior to the experiment, the subject was screened for general health. She did not rate as an extreme chronotype. The subject signed an informed consent form.

Three days prior to the experiment and during the experiment in the lab, the subject refrained from consumption of alcohol and caffeine, and was instructed to sleep from 00:00-08:00 hours. This was confirmed by using a wrist-worn actimeter. The experiment took three consecutive days in the lab. On day 1, the subject was invited to the lab at 20:00 hours for adaptation to the experimental procedures. The EEG electrodes (Electrocap Inc., see below) were applied and the subject was asked to go to sleep at 00:00. After sleeping, the cap was removed and the subject returned to her normal daily routine. The evening of day 2, the subject was again invited at 20:00 and the same

procedure was applied. After sleeping, the subject stayed awake during the next 40 hours. This was verified by actimetry and personal observation of the experimenter. After 40 hours waking, the subject was allowed to sleep again between 00:00-08:00. The next morning, the cap was removed and the experiment was ended. Throughout the waking phases, regular test sessions were run to assess performance and subjective sleepiness.

Data acquisition

Sleep EEGs were recorded at 28 locations using an Electrocap, equipped with Ag/AgCl electrodes. Recorded electrodes were located above the pre-frontal and frontal cortex (FP1, FP2, F7, F3, Fz, F4, F8), central cortex (C3,Cz,C4), temporal cortex (T6, T3, T4, T5), parietal cortex (P3,Pz,P4,P9,P10,PO9,PO7,PO8,PO10) and occipital cortex (O9,O1,Oz,O2,O10). One electrode attached to the left earlobe (A1) served as common reference. A common ground electrode was placed at the inion on the lower forehead. Furthermore, EOG and EMG were recorded to facilitate scoring of sleep stages. EEG signals were amplified (500µV/V) and band-pass filtered (-3dB points at 0.05Hz and 30Hz).

Auditory stimulation procedure

During test session and during sleep, trains of tone pips were delivered in the external ear canal using small earphones (Sennheiser) with foam earplugs. A train of stimuli consisted of 15 tones of 1000 Hz (75% of stimuli) or 2000 Hz (25% of stimuli) at 65dB. Between two trains of tones there was a 15 seconds inter-stimulus interval in which undisturbed EEG was recorded for power analysis.

Data analysis

EEG data were analyzed using a specialized commercial software package (BrainVision). EEGs were scored for vigilance states (Rechtschaffen & Kales 1968). Stage 2-4 NREM sleep EEGs were used for further analysis. NREM sleep EEG power analysis was performed by analyzing 15 sec NREM sleep episodes in between auditory stimulation trains. These 15 sec NREM sleep EEG signals were screened for artifacts and fast-Fourier transformation (FFT) was conducted on undisturbed intervals. Slow wave activity (SWA, EEG power between 1-4Hz) was derived from the FFT spectra for further analysis.

AEPs during NREM sleep were calculated for 1000 Hz and 2000 Hz pip stimuli combined. EEG traces of 800 ms after stimulus occurrence were taken as AEP. AEPs were averaged per 15 sec stimulus train for generating average AEP amplitudes for further analysis. Associations between SWA and AEP amplitude were made by performing Pearson correlations between SWA of a certain 15 sec interval and the AEP amplitude for all 10 ms intervals (80 intervals) of the average AEP recorded during the 15 sec interval immediately prior to the EEG used for SWA calculation.

Results and Discussion

The associations between SWA and AEP amplitude are shown in a contour plot for the midline scalp locations Fz, Cz, Pz and Oz for the 800 ms post-stimulus interval of the AEP. Significance levels of the correlations were

Bonferroni corrected to adjust for multiple testing (n=473 intervals: p=0.000625, yielding a critical correlation coefficient of r=+0.16 or -0.16).

The contour of r=-0.16 in Figure 1 thus depicts the border of a significant negative correlation area of predominantly the central locations in the AEP amplitude between 280 – 730 ms and the SWA during the subsequent NREM sleep EEG: the higher sleep intensity, the more negative the AEP amplitude in this range. The timing of this negative association between SWA and AEP amplitude suggests that a late negative aspect, possibly the N550 (Cote et al. 1999), is negatively associated to SWA. As tentative functional implication, this association may indicate that the late negative aspect has something to do with stimulus processing or the suppression of stimulus processing, since sleep intensity is negatively associated with the wake-up threshold.

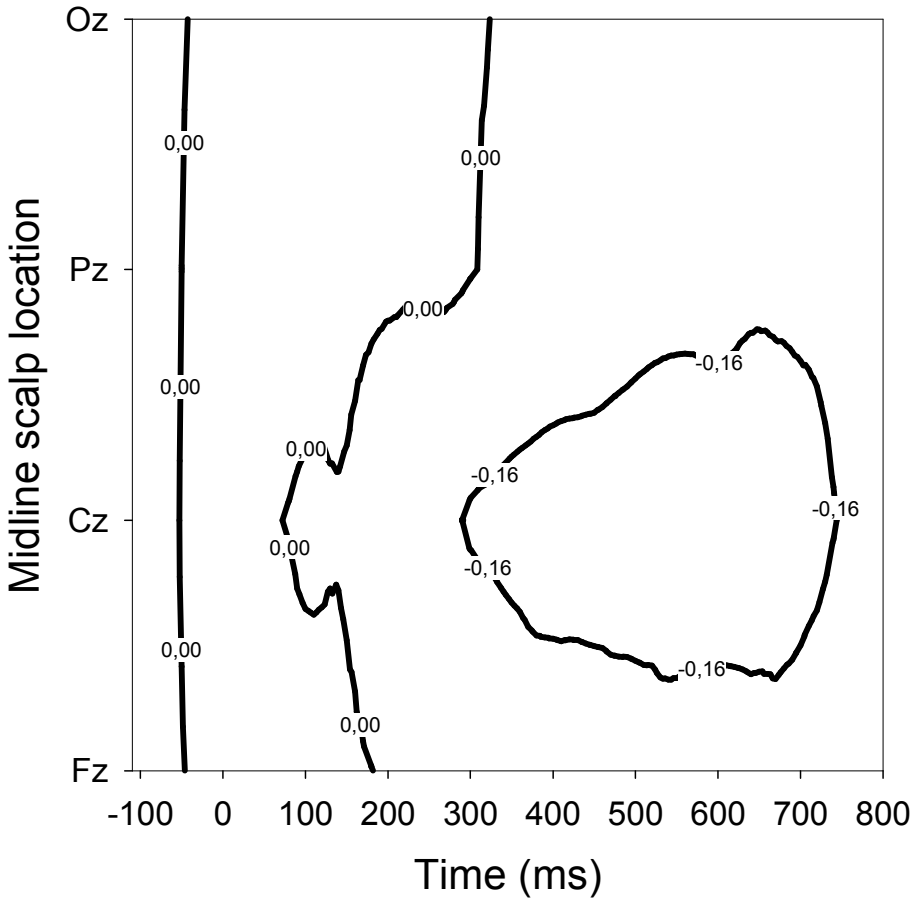

Figure 1. Contour plot of the correlation coefficients r, calculated for the associations between slow wave activity (SWA) and auditory evoked potential (AEP) amplitude for the midline scalp locations Fz, Cz, Pz, and Oz. Associations were considered significant when r>0.16 or r<-0.16 (see text). Significant negative associations were observed around the Cz location between 280-730ms, mimicking the timing of the N550 (Campbell et al. 1992).

References

1. Campbell, K.B., Bell, I., Bastian, C. (1992) Evoked potential measures of information processing during natural sleep. In Broughton, R.J. & Ogilvie, R.D. (eds) *Sleep, arousal and performance*, Birkhäuser, Boston, 1992, pp 88-116.
2. Cote, K.A., De Lugt, D.R., Langley, S.D., Campbell, K.B. (1999) Scalp topography of the auditory evoked K-complex in stage 2 and slow wave sleep. J. Sleep Res. 8:263-272.